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Measurement of resident workload in paediatric intensive care

Frey, Bernhard ; Hossle, Johann Peter ; Seiler Sigris, Monika ; Cannizzaro, Vincenzo

Abstract: **OBJECTIVE:** To measure the workload of residents in a paediatric intensive care unit (PICU) and to compare this value with the possible explanatory variables "nine equivalents of nursing manpower use score" (NEMS), length of stay (LOS), patient age and severity of illness at admission. **METHODS:** This was a prospective study in a tertiary, interdisciplinary neonatal-paediatric intensive care unit. In 2010 and 2011, residents estimated their workload for each patient they looked after at admission and then twice a day (morning and night shift) (minor workload 0-30 minutes, medium >30-90 minutes, high >90 minutes). The following demographic and illness severity parameters were also collected prospectively: age, LOS, NEMS, Paediatric Index of Mortality (PIM2), and main diagnosis at admission. **RESULTS:** There were 2,513 admissions to PICU. Independent predictors of residents' workload were LOS (coefficient in multiple regression 8.9, $p < 0.0001$) and NEMS (coefficient 1.4, $p < 0.0001$). R^2 of 0.928 indicated a strong overall relationship. Severity of illness at admission and patient age did not explain overall workload for the whole patient stay in PICU. **CONCLUSIONS:** NEMS, a therapeutic intervention score, and LOS are both independent predictors of clinical workload of residents in PICU. The correlation with LOS means that workload depends mainly on routine procedures (rounds, discussions with parents, administrative tasks) unrelated to the severity of illness. After calibration, LOS or NEMS, two widely used measures, may be used to calculate resident workload.

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Measurement of resident workload in paediatric intensive care

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Summary

OBJECTIVE: To measure the workload of residents in a paediatric intensive care unit (PICU) and to compare this value with the possible explanatory variables “nine equivalents of nursing manpower use score” (NEMS), length of stay (LOS), patient age and severity of illness at admission.

METHODS: This was a prospective study in a tertiary, interdisciplinary neonatal-paediatric intensive care unit. In 2010 and 2011, residents estimated their workload for each patient they looked after at admission and then twice a day (morning and night shift) (minor workload 0–30 minutes, medium >30–90 minutes, high >90 minutes). The following demographic and illness severity parameters were also collected prospectively: age, LOS, NEMS, Paediatric Index of Mortality (PIM2), and main diagnosis at admission.

RESULTS: There were 2,513 admissions to PICU. Independent predictors of residents' workload were LOS (coefficient in multiple regression 8.9, $p < 0.0001$) and NEMS (coefficient 1.4, $p < 0.0001$). R^2 of 0.928 indicated a strong overall relationship. Severity of illness at admission and patient age did not explain overall workload for the whole patient stay in PICU.

CONCLUSIONS: NEMS, a therapeutic intervention score, and LOS are both independent predictors of clinical workload of residents in PICU. The correlation with LOS means that workload depends mainly on routine procedures (rounds, discussions with parents, administrative tasks) unrelated to the severity of illness. After calibration, LOS or NEMS, two widely used measures, may be used to calculate resident workload.

Key words: *physician manpower; paediatric intensive care unit, NEMS*

Introduction

Physician manpower can be calculated from the needed manpower time per year ([24h coverage + handover time] x 365) divided by the net working time per fulltime equivalent per year (total working time, minus holidays, minus training, minus non-patient related duties) [1]. However, there are no clear rules or guidelines to estimate the needed manpower time. It may depend on the organisational struc-

ture of the paediatric intensive care unit (PICU) and the mean severity of illness of the patients looked for. According to the European Society of Intensive Care (ESICM), one full time equivalent physician qualified in intensive care medicine can look for 6–8 patients at level of care II [1]. Therefore, physician workload depends on local circumstances. Furthermore, in a consultant – resident system, workload of the respective professions depends on the distribution of work between them.

Restriction of resident work hours over the last years has resulted in shift length reduction and increased manpower demand. Duty hour limits also came along with increasing complexity in patient care, reduced time of training, and decreased direct patient care. On the other hand more frequent handovers are paralleled by risks of information errors and/or incomplete communication [2]. Hence, assessment and estimation of workload is essential for manpower analysis and prediction and both work distribution and allocation. It is important to mention that stress at work is not only related to the time spent in the job and the effort put into it, but results more on effort-reward imbalance within work and imbalance between the work and the family domain [3].

For ICU nurses, NEMS (nine equivalents of nursing manpower use score) is a suitable therapeutic index to measure workload [4]. In adults, there is a good agreement between TISS-28 (Therapeutic Intervention Scoring System) and NEMS [5]. TISS and NEMS may be used to evaluate the adequacy of planning and practice in nursing staff, to define the level of care, to estimate workload, to measure general resource use and to calculate costs [5–7].

The aim of this study was to measure the workload of residents in a PICU and to compare this value with the possible explanatory variables NEMS, length of stay (LOS), age and severity of illness at admission. We wanted to find surrogate measures, already taken on a routine basis, for resident workload. We hypothesised that workload is associated with severity of illness at admission and nursing workload

Methods

This was a prospective study in a tertiary, interdisciplinary neonatal-paediatric intensive care unit (18 beds in 2010, 23 beds in 2011). The unit includes post cardiac surgery patients and runs an extra-corporeal-membrane-oxygenation- (ECMO) programme. About 25% of patients are in the neonatal age-group, mainly neonates with cardiac and/or surgical pathologies.

Residents are working on a three shift roster. There are two residents in each shift and about half of weekdays morning shifts are covered by a third resident. Residents are supervised by consultants: on weekdays two consultants at day-time and one consultant at night-time; on weekends, one consultant each at day- and night-time.

In the 24 month study period 2010 and 2011, residents had to give their estimated workload for each patient they looked after, at admission and thereafter for the morning and night-shift. They had to choose between low workload (0–30 minutes), medium workload (>30–90 minutes) and high workload (>90 minutes). These three categories were chosen arbitrarily. The data were entered into the hospital information system which was set up so that working with the respective patient file was only possible after having clicked on the button “physician workload”. The “workload button” was linked to the progression note field, which had to be filled in twice a day (for the morning and night shift). Writing a new progression note was thus only possible after having chosen the estimated workload for the respective patient. This electronic feature enabled a comprehensive workload dataset. “Workload” included direct patient care (rounding, procedures, patient transport, talk-

ing to the patient etc.) as well as indirect patient related work (up dating of case history, discussion with parents, communication with insurances etc.). New residents were instructed about this tool and regular spot checks were performed by B.F. as a quality control measure (once a week, B.F. discussed with a resident the workload entries of his/her previous shift).

The following demographic and illness severity parameters were also collected prospectively (minimal data set, Swiss Society of Intensive Care [8]): age, LOS in PICU, expected mortality at admission (PIM2: Paediatric Index of Mortality [9]), artificial ventilation (invasive and non-invasive), diagnosis (main diagnosis at admission, according to the Australian and New Zealand Paediatric Intensive Care Registry, ANZPIC [10]) and NEMS [4]. NEMS was adapted to children [8]. NEMS was collected by nurses for each shift (3 shifts per day). NEMS includes the following nine items (points assigned to each item in parentheses): basic monitoring (9), intravenous medication (6), mechanical ventilatory support (12), supplementary ventilatory care (3), single vasoactive medication (7), multiple vasoactive medication (12), dialysis techniques (6), specific interventions in PICU (5) and specific interventions outside the PICU (6) [5]. The range of possible score points per patient and shift is 0 to 66.

Statistics

For each patient stay in PICU, the following parameters were presented on a excel sheet: PIM, LOS, age, total NEMS points, and total workload (in minutes). For workload calculation the following times were attributed to the three workload categories: low workload: 30 min; medium workload: 60 min; high workload: 120 min. These times were derived from a calibration sample of 25 shifts (mean values for low workload: 28 minutes, medium workload: 58 minutes and high workload: 123 minutes). Total workload was calculated by adding the respective times of the admission work and of each shift thereafter of the whole PICU stay. For each parameter summary statistics was calculated (mean, SD; median, range). Univariate and multiple regression analyses were done for workload as the dependent parameter and PIM, NEMS, LOS and age as independent parameters. A $p < 0.05$ was considered significant.

Results

There were 2,513 admissions to intensive care with 32,686 nursing shifts (related to each separate patient). Almost half of the admissions were unplanned (47.1%) and 52.4% of the children received artificial ventilation (invasive and non-invasive). The number of patients in the main diagnostic groups and the 10 most frequent individual diagnoses are given in table 1. Mortality in PICU was 2.67% (standardised mortality ratio, SMR, 0.68).

Table 2 shows summary statistics of workload, NEMS, LOS, age and PIM2. Of all workload entries, 20.7% were related to low workload, 56.6% to medium workload and 22.7% to high workload. Univariate regression analyses with workload as the dependent variable are shown in table 3 and figure 1 and multiple regression analysis in table 4.

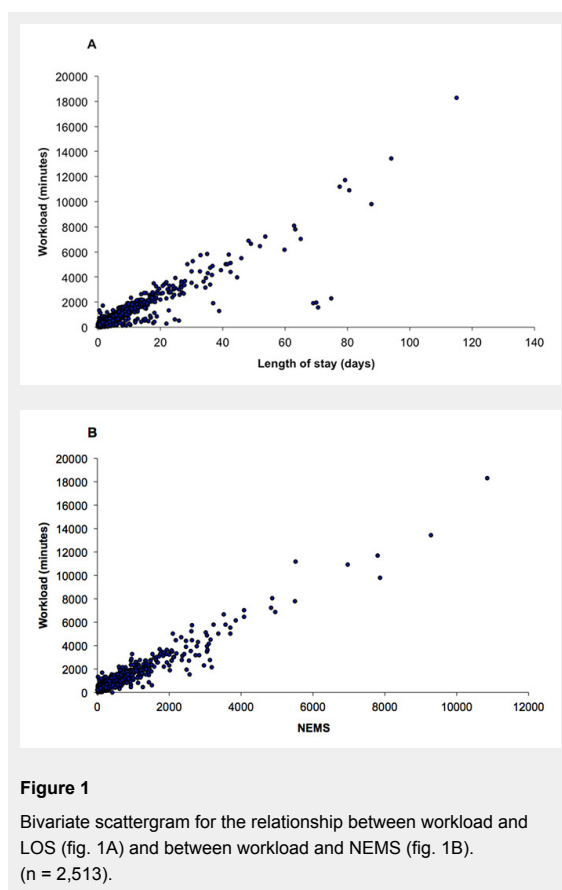


Figure 1

Bivariate scattergram for the relationship between workload and LOS (fig. 1A) and between workload and NEMS (fig. 1B). (n = 2,513).

In multiple regression, R^2 of 0.928 indicates a strong overall relationship, that is, the model predicts 92.8% of the variability of residents' workload. Figure 1a (scattergram for workload vs LOS) shows that there may be two cohorts of patients with different slopes: long stayers with low overall workload and long stayers with high workload. Dividing the workload for all patients by the NEMS points for all patients gives 2.3 minutes workload for 1 NEMS point. Dividing the workload for all patients by the LOS for all patients gives a mean workload of 149 min for one patient-day. Given an average bed number of 20.5 for the two years and bed occupancy of 85%, the average number of patients per day in ICU was 17.4. Therefore, the total resident workload per day was $17.4 \times 149 \text{ min} = 2593 \text{ min}$ (43.2 hours). However, in our study, workload-hours were entered only for the work at patient admission and the ongoing work in the morning and night shifts. For the after-

noon shifts, no workload was entered. Therefore, the mean workload per day (43.2 hours) may be higher.

Discussion

Independent predictors of residents' workload were LOS and, to a lesser degree, NEMS. Severity of illness at PICU admission and patient age did not explain overall workload for the whole patient stay in PICU.

The absent correlation between workload and severity of illness at admission and the close correlation between workload and LOS, are indications that residents' workload depends mainly on structural and organisational characteristics of a PICU [11]. The Swiss working law and the number of PICU subunits, particularly if located in different areas of the hospital (as in our case), dictate the number of residents. Usually there are 6-8 beds in one PICU subunit [1]. Furthermore, a lot of residents' tasks are unrelated to severity of illness and nursing workload. Examples of such tasks are: daily rounds, discussions with patients' parents, and administrative work. However, there may be two groups of patients (see fig. 1a): less ill patients (related to the whole PICU stay) with low overall workload and severely ill patients with high overall workload. Therefore, workload may be associated with a severity score which is calculated on a daily basis (and not just at admission, like PIM2). NEMS is also an independent predictor of residents' workload in our study. The NEMS items include not only nursing activities but are also related to residents' activities, at least in the practice of intensive care in our PICU: e.g. residents are involved in the management of mechanical ventilation and dialysis (items 3 and 7), they are performing specific interventions, such as endotracheal intubation, introduction of venous or arterial lines (item 8) and they are involved in patient transport for specific interventions outside the PICU (item 9), furthermore, patients on vasoactive drugs (items 5 and 6) need closer clinical observation. NEMS may be used to estimate the needed phys-

Table 1: Distribution of main diagnoses at admission to PICU (ANZPIC registry diagnostic codes [10]) (n = 2,513).

Main diagnostic groups (order as in the original publication [10])	n
Injury	132
Cardiovascular	258
Neurological	196
Respiratory	376
Renal	28
Gastrointestinal	68
Miscellaneous	247
Post-procedure: Miscellaneous/Anaesthetic	211
Post-procedure: Cardiac surgery	435
Post-procedure: Neurosurgery	126
Post-procedure: Thoracic surgery	45
Post-procedure: ENT surgery	67
Post-procedure: Abdominal/General surgery	179
Post-procedure: Craniofacial surgery	48
Post-procedure: Orthopaedic surgery	97
Individual diagnoses (10 most frequent)	
Seizures	98
Cardiac catheter, interventional	76
Orthopaedic surgery, other	69
Post-procedure, other	65
Cardiac catheter, diagnostic	63
Respiratory failure	63
Ventricular septal defect repair	60
Pneumonia or pneumonitis	54
Craniotomy, anterior fossa	48
Trauma, head	46

Table 2: Summary statistics per patient (n = 2,513).

	Mean (SD)	Median (range)
Workload (min)	609 (968)	330 (30–18,300)
NEMS (points)	296 (632)	105 (0–10,855)
LOS (days)	4.1 (7.9)	1.8 (0.01–115)
Age (years)	4.1 (5.3)	1.3 (0–25.5)
PIM (%)	3.90 (9.85)	1.39 (0.02–99.82)

Table 3: Univariate regression analyses. Workload (min) is the dependent variable (n = 2,513).

		R^2	p
NEMS (points)	Workload = $172.9 + 1.5 \text{ NEMS}$	0.93	<0.0001
LOS (days)	Workload = $145.0 + 111.9 \text{ LOS}$	0.84	<0.0001
Age (years)	Workload = $705.1 - 23.3 \text{ Age}$	0.016	<0.0001
PIM (%)	Workload = $560.5 + 11.6 \text{ PIM}$	0.016	<0.0001

Table 4: Multiple regression analysis. Workload (min) is the dependent variable (n = 2,513). R squared for the whole regression is 0.928.

	Coefficient	Standard error	Standard coefficient	t-value	p
Intercept	166	7.7	166	21.6	<0.0001
LOS (days)	8.9	2.0	0.07	4.43	<0.0001
NEMS (points)	1.4	0.03	0.89	54.0	<0.0001
PIM (%)	0.12	0.53	0.001	0.23	0.82
Age (years)	0.17	1.0	0.001	0.18	0.86

ician manpower, in addition to structural and industrial law related issues.

Our tool of measuring workload was well accepted by residents and easy to use. Demands on time for this additional administrative task was minimal, because residents had only to click on one of three workload options (low, medium and high workload). Probably a more precise, but also much more complicated methodology to measure workload has been described by Zupancic et al. [12] in a neonatal intensive care unit. In this study, observers (one observer per patient) used a stopwatch to time all interactions between the patient and personnel (nurse, attending neonatologist, nurse practitioner, fellow and respiratory therapist). Because of the troublesome design, observing episodes were restricted to 8 to 12 hours and in total only 154 neonates were observed. As in our study, multiple regression was performed with workload as the dependent variable and illness severity, infant characteristics and resource markers derived from the Neonatal Therapeutic Intensity Scoring System (NTISS) as independent variables. For physicians and nurse practitioners combined, the model predicted only 23% of the workload variability ($R^2 = 0.23$, $p < 0.0001$) [12]. In contrast to our tool, the methodology of the study of Zupancic [12] is not practicable on a routine basis and indirect patient care which makes up a significant part in residents' daily work, is not recorded.

There are some limitations to our study. Firstly, residents' workload was entered only in two of the three daily shifts (in addition to entering the workload related to the admission of a new patient). In order to generate a comprehensive dataset, the workload entry into the hospital information system was linked to the clinical progression notes of each patient, which were done only twice a day. However, as the resident of the afternoon shift is mainly admitting new patients and the continuous patient care is mainly done by the resident of the morning shift (07.30h–18.00h) and the resident of the night shift (22.30h–08.30h), the lack of these data should not, in the end, weaken the qualitative conclusions. Further, we are not able to present data on workload per patient-day or on variation in work load per day over the patients' whole length of stay. Of course, it would be very interesting to know whether there is a trend in terms of when in the patient's hospitalisation the work load is greatest or least and whether there is any variation in this by diagnosis. Secondly, in a consultant – resident system such as ours, residents' workload depends on the consultants' involvement in patient care. Depending on whether a consultant takes on direct patient care or not (e.g. manual procedures), the resident may have time to perform other duties at the same time. There may be differences between individual consultants regarding their involvement in patient care and the level of training of residents may also play a role. We did not analyse these issues. Thirdly, several further tasks of residents were not recorded, such as further education (active teaching to colleagues and nurses; receiving of teachings), participation in working groups, administrative work for the PICU (e.g. elaboration of the roster), research, and clinical work with patients not assigned to the respective resident. Our study focused on patient care. It is important to differentiate between the three main tasks of physicians in university hospitals, that is clin-

ical work, education/teaching, and research. In our institution, these tasks are mingled and we wanted to contribute to some breaking up. Finally, it is important to stress, that the findings of the study are dependent on local practice patterns and case mix. One of the chosen surrogate measures, i.e. NEMS is specific to intensive care, which further limits the generalisability of the results, and their utility for other medical fields. We encourage others to repeat this study in different settings to confirm our findings or to distil those factors that determine the workload in a more global setting.

In conclusion, NEMS, a therapeutic intervention score, and LOS are both independent predictors of clinical workload of residents in PICU. The correlation with LOS means that workload depends mainly on routine procedures (rounds, discussions with parents, administrative tasks), unrelated to the severity of illness. After calibration, LOS or NEMS, two widely applied measures, may be used for resident workload calculation, at least in our institution. Further, a semi-quantitative recording of time spent for each patient, as used in this study, may be an easy to use and practicable tool for a more precise estimation of physician manpower need in PICU.

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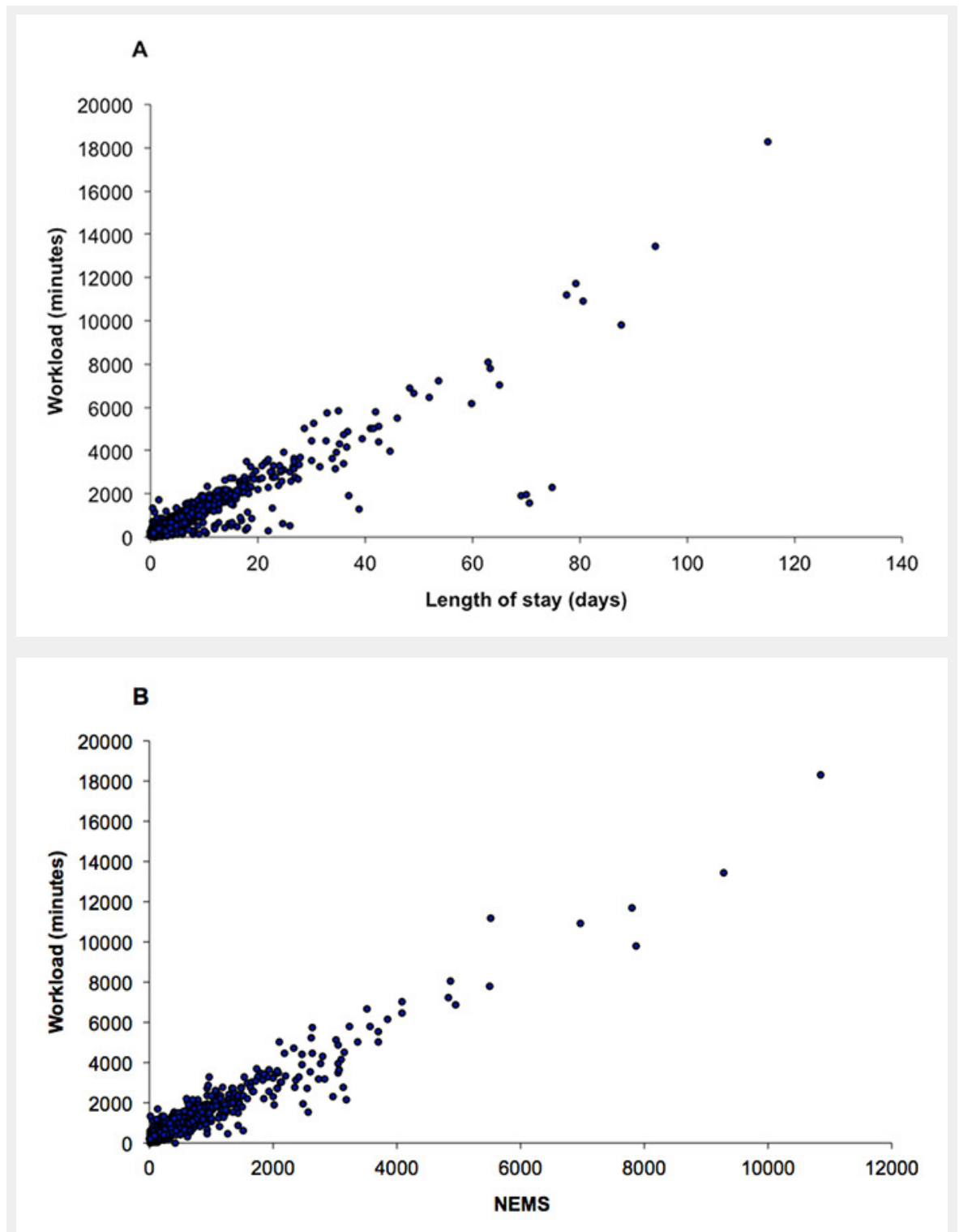
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Figures (large format)

**Figure 1**

Bivariate scattergram for the relationship between workload and LOS (fig. 1A) and between workload and NEMS (fig. 1B). (n = 2,513).